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# Creating interaction environments: Defining a two-sided market model of the development and dominance of platforms

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**Abstract.** Interactions between individuals, both economic and social, are increasingly mediated by technological systems. Such *platforms* facilitate interactions by controlling and regularizing access, while extracting rent from users. The relatively recent idea of two-sided markets has given insights into the distinctive economic features of such arrangements, arising from network effects and the power of the platform operator. Simplifications required to obtain analytical results, while leading to basic understanding, prevent us from posing many important questions. For example we would like to understand how platforms can be secured when the costs and benefits of security differ greatly across users and operators, and when the vulnerabilities of particular designs may only be revealed after they are in wide use. We define an agent-based model that removes many constraints limiting existing analyses (such as uniformity of users, free and perfect information), allowing insights into a much larger class of real systems.

**Keywords:** Two-sided markets, platform economics, platform competition, agent simulation

## 1 Introduction

A *platform* is a collection of equipment, facilities, and standards that facilitates a particular kind of interaction. Telecommunications systems, social networking sites, the internet as a whole, DVD players, and credit card networks are a few examples of the platforms that increasingly mediate interactions among people and institutions. Rochet and Tirole [1] and Evans [2,3] recognized the distinctive economic features of these systems, and initiated their formal study as two-sided markets. Many important results have been derived in the short time since, however almost all are derived for



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systems simple enough to be treated analytically. Some common assumptions include perfect information about demand functions, homogeneity of demand, and uniformity of fees across users of a given class. Most analyses obtain equilibrium results rather than exploring the dynamics of platform development and adoption. Because the basic dynamics contain reinforcing feedbacks (for example platform attractiveness to prospective users increases with the number of current users) the equilibrium configuration is likely to be sensitive to small variations in development details.

Some of these analytical constraints are being removed by ongoing research. For example Alexandrova-Kabadjova et al. [4] use an agent-based model to study platform competition when geographical constraints influence interactions. The influence of platform security on users' adoption decisions has received little attention, despite the increasing use of platforms to carry personal and financial data. Creti and Verdier [5] have pioneered the study of fraud costs and liability allocation on platform selection using a staged optimization model amenable to analytical solution.

The agent-based model defined here removes constraints that analytical approaches impose. We focus on the interacting decisions of platform users and creators, including users' decisions to subscribe to or abandon a particular platform, creators' decisions to allocate tariffs and to invest in capacity and marketing. Because we are especially interested in platform security, the model includes intruders' decision to attack the platform in a way that imposes costs on users and creators. The prospect of such losses is a factor in users' adoption decisions and creators' investment decisions.

## 2 Platforms as two-sided markets

In economic terms platforms create two-sided markets. They are used to interconnect two sets of users, which constitute the sides of the market. Sides typically play distinct roles, such as merchants and credit card customers, or application developers and application users, or musicians and audience. The two sides may use very different technology to connect to the platform, and may face different connection costs and fee structures. The platform operator creates and maintains the infrastructure, and gets revenue from one or both sides of the market.

The different costs faced by different kinds of users, and the platform operator's ability to determine prices and control access, can lead to surprising strategies for optimizing operators, such as subsidizing one side of the market at the expense of the other. The very recent recognition of two-sided markets as a distinctive category has produced important general insights of this kind; however almost all are derived for systems simple enough to be treated analytically.

The increasing variety of platforms through which economic and social interactions are conducted suggests that a model general enough to provide broad insights, yet rich enough to relax assumptions that constrain analytical approaches, would be a useful way of understanding, and setting policies for, important systems of this kind. We define such a model below by describing the essential dynamics of the system. Building from the basic interactions characteristic of two-sided markets, we demonstrate how operators' investments on performance and security can bring in new constraints on the adoption and use of platforms.

## 3 Model Components and Behavior

The model includes the basic classes of Platform, Operator, and User (Fig. 1). The systems of interest typically have two major subclasses of Users which define the sides of the two-sided market. One class is often a Producer of some good or service or content, while the other is a Consumer. Figure 1 shows the three principle classes and the flows of value considered in the model. These values create motivations for the actions of each class of decision maker. How the Platform creates these values depends on intrinsic features of the domain, performance properties of the Platform, and the number of users of the Platform. The model can be applied to specific cases by specifying parameter values, however the components of the model and their dynamics are meant to be generally applicable.

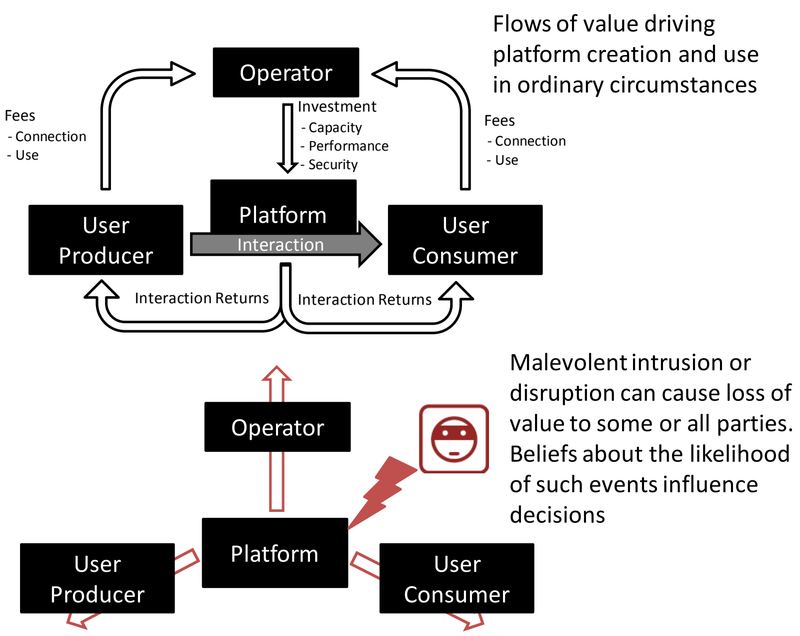


**Fig. 1 –** Main classes in the platform model, and flows of value created by platform use and intentional disruption.

Users derive some benefit from interacting on the Platform, and pay fees to the Operator, generally for both access and for usage. Often these fees are explicit; however they might be imposed indirectly, by means of advertising for example. There may be more than one Platform available to Users, so that Users can choose to subscribe to or use alternatives on the basis of their costs and returns. Operators can set the subscription and usage fees borne by each user, and these might vary across users.

Some platforms, especially those mediating financial transactions, compete on the basis of security. We include security as a consideration by means of random acute costs, which can be imposed on individual Users, on groups of Users, and on the Operator. These costs represent losses that would occur as a consequence of a security breach, such as theft of assets or expenses incurred as a result of identity theft. User's expectations about such costs will influence their platform choice and use. These expectations are based on prior beliefs, on the actual security history for the platform, on reports of trusted social contacts, and on marketing messages created by the Operator. Operators, in turn, may invest in security measures that reduce costs or probabilities of a breach as well as in marketing messages designed to shape Users' beliefs about the security of their Platform and other Platforms. Operators' interest in maintaining security comes both from costs they might incur as a direct consequence of a breach and costs of any loss of subscribers or usage arising from Users' changed perception of risk.

### 3.1 Model of Producer and Consumer Behavior

The success or failure of a particular platform, and the value produced for its users, are the result of interacting decisions by the Operator and by members of the two subclasses of User, Producers and Consumers. We assume Users derive some specified basic value from conducting a single transaction of the kind the platform supports. This basic value may be different for Producers and Consumers, but is the same for all platforms that compete for Users' business. Platforms differ in the number of transaction opportunities they provide, and in the costs they present to Users. Some of these costs can be directly controlled by Operators, while others are the indirect consequences of decisions Operators make, such as investments in capacity and security. These costs and decisions are the strategic variables that Operators use to compete for market share and profit.

The dynamical model of Users' decisions about their participation in a particular platform is shown as a causal loop diagram[2] in Figure 2. The defining dynamical feature of platforms is the reinforcing feedback that causes an increase in the number of producers using the platform to attract additional consumers, and vice-versa. Such two-sided network effects have been identified in many technological systems [6].

[2] Causal loop diagrams are qualitative model specifications showing the variables considered in the model and the causal relationships between pairs of variables. The effect of increasing the value of a variable on causally dependent variables is indicated by a +/- sign near the arrow to the dependent variable.

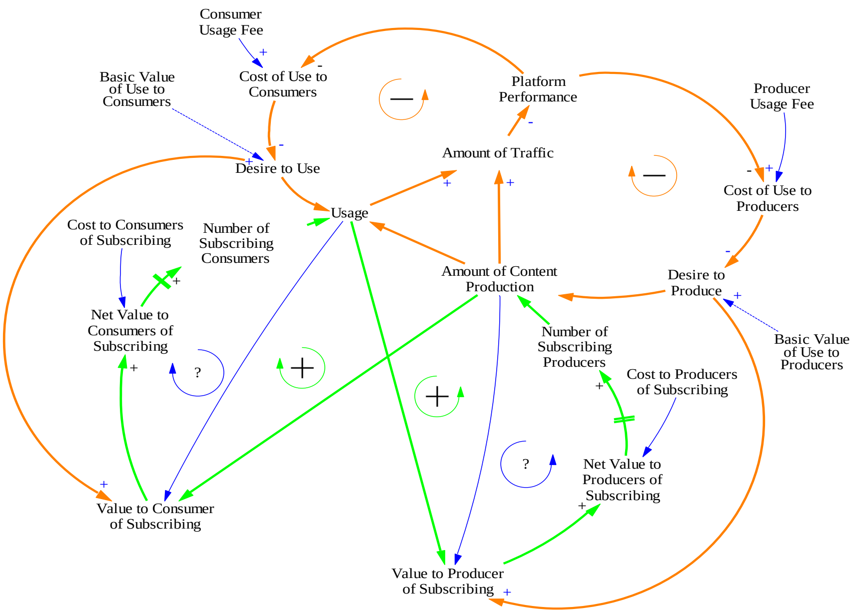


**Fig. 2.** Causal loop diagram showing the dynamics of platform subscription and usage by producers and consumers. The central reinforcing feedback can lead to exponential growth (or collapse) as additional users of one kind increase the value of using the platform to users of the other kind. Increased traffic on the platform may degrade users' perceived performance and limit growth.

This reinforcing feedback can lead to exponential growth in platform users, as well as to exponential collapse, depending on how users' costs compare with the benefits they obtain from using the platform, and the costs presented by competing platforms. The basic value that a user obtains from a single transaction on the platform is exogenous. The model distinguishes subscription to the platform, which involves getting whatever equipment and authorization is required to use it, and usage, which involves conducting transactions on the platform. These two actions may have very different costs, which differ between producers and consumers. Platform operators can try to encourage growth by manipulating those aspects of costs that they can control. For example a new platform with few producers or consumers will present little value for either side to subscribe. Initial subsidies for subscription, reducing or inverting subscription costs, may attract enough initial users to allow the subsidy to be eliminated for later subscribers. The subscription costs and usage fees in Figure 1 are two important targets of operators' decision-making.

### 3.2 Model of Operator Behavior

Many existing analyses of two-sided markets derive pricing strategies for operators which maximize their profits, given differing price sensitivities of producers and consumers [1]. In these analyses Users' costs can be directly controlled by Operators.

Many systems impose significant indirect costs on Users which may have considerable influence on their decisions, but which are not directly controllable by operators. We include the effects of platform performance and security as indirect costs. Figure 2 shows the potential for increased platform usage to degrade performance and so increase the usage costs of consumers or producers. This increased cost can place limits on prospective users' uptake of a platform. Investments in capacity can be used to improve performance and encourage further growth. The transactions hosted on many platforms have a financial component, and some platforms (such as credit cards) are specifically designed for financial purposes. The security of such platforms is a special concern to users. Security compromise might lead to loss of personal information, initiation of fraudulent transactions in the guise of legitimate users, corruption or blockage of transaction data, and many other undesirable consequences. Such events might lead to direct financial loss to users, or simply to inconvenience and delays which we represent as an indirect cost. Users do not need to experience such events directly in order to weigh such costs in their decisions to subscribe to and use the platform. The expectation of loss from lax security, which includes both the prospective cost of a breach and the users' probability that a breach will occur, is included as a component of cost. Managing platform security, and users' perceptions of security, is a second means by which operators can indirectly control costs.

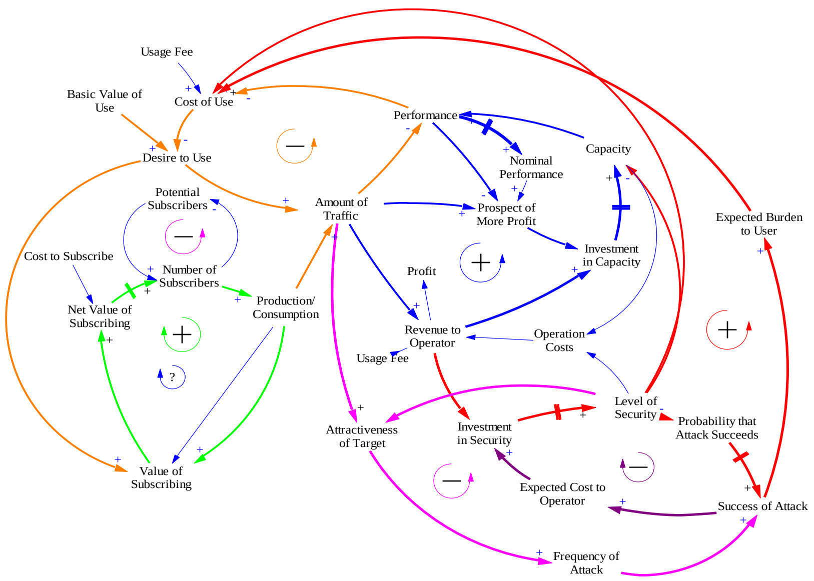


**Fig. 3 -** Causal loop diagram showing the dynamics of platform operator's behavior. Platform growth can be driven by investments leading to improved performance and greater security. Perceptions of improved security may lag investments in security, and reductions in security may take time to manifest as attacks. These delays can create oscillations in security investment.

Figure 3 elaborates the causal loop diagram to include the dynamics of operator behavior. In this diagram the two kinds of platform user have been collapsed into one in order to simplify the picture. Operators receive revenue through platform use. They invest in both expanding platform capacity and in securing access and traffic from this revenue. The linkage between revenue and investment reflects the possibility of direct reinvestment as well as loans secured by future revenue.

The platform operator can encourage growth by making investments that improve platform performance and that increase security. Both kinds of investment tend to lower the effective cost to a user of transacting on the platform. Performance improvements are shown as coming from an increased capacity, although other platform changes that facilitate use (such as redesigning interfaces) can have a similar effect. Capacity investments may be reactive – driven by performance problems with the existing system – or proactive – driven by trends in the current usage which anticipate constraints on performance.

Investments in security are motivated by threats of attack. The kind of attack that might be staged and the costs imposed by successful attacks depend on the specific platform being considered. A denial of service attack for example might delay users' business operations and might degrade the reputation of the platform operator. Theft of credit-card data might lead to financial losses to issuing banks and inconvenience costs to cardholders. A successful attack will increase (to some degree) both the operator's and users' estimated costs, leading to increased investment in security by operators and possible changes in usage. An increased investment in security will reduce the probability of successful attack to some degree, lessening users' perceived costs and encouraging growth in platform use. There can be significant delays in this process, both in deploying security measures and in changing users' perceptions, so that the return on security investments may come long after expenses are incurred. Heightened security can impose burdens on the system and its users. These effects are shown in Figure 3 as a possible reduction in capacity and a possible increase in user costs driven by increases in the level of security.

The threats faced by a particular platform are also dynamic, and the model includes two important factors influencing the attractiveness of the platform as an attack target. The current level of security can deter attack or cause it to be directed elsewhere. The amount of traffic on the platform is assumed to make it more attractive as a target, whether the object is financial gain or spectacle. Increased attractiveness leads to more frequent attack attempts, and a greater incidence of successful attack.

## 4 Model Analysis and Development Status

The causal model defined above represents the processes that can determine the outcome of competition among platforms when the operators of those platforms adopt different strategies. Even without a precise formulation of the relationships represented by the causal links, the basic feedback structures can produce insights into possible behavior. For example Figure 3 suggests two mechanisms by which an operator might try to expand their platform: investing in capacity to improve nominal performance; and investment in security that decreases users' expected costs. While there are potential delays in realizing performance improvements through new capacity, the delays between an investment in security and an improvement in users' perception may be much greater, especially in system characterized by infrequent but costly attack. This suggests that a strategy emphasizing capacity expansion might out-compete a strategy emphasizing platform security, particularly in a market with rapid growth rates.

A mathematical specification of the causal links illustrated in Figures 2 and 3 is necessary to study particular systems. Such specification allows simulation of possible histories of subscription and use resulting from different user dispositions, costs, and operator policies. We are currently developing an application to retail payment systems, using an agent-based framework that allows for heterogeneous populations of Consumers and Producers, price differentiation by Operators, and other properties that characterize the real system but that make analytical approaches intractable.

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